CLAIMS

What is claimed is:

1. Apparatus for electrical testing of an electrical circuit having first and second side surfaces and including a plurality of conductors, the apparatus comprising:

at least one stimulation electrode disposed adjacent at least one of said first and second side surfaces of said electrical circuit and being operative to apply thereto a stimulation electromagnetic field in a non-contact manner;

at least one sensing electrode disposed adjacent at least one of said first and second side surfaces of said electrical circuit and being operative to sense a resulting electromagnetic field produced by application of said stimulation electromagnetic field at various locations thereon in a non-contact manner;

wherein at least one of said at least one simulation electrode and said at least one sensing electrode includes at least two electrodes at least one of which is disposed adjacent each of said first and second side surfaces of said electrical circuit.

2. Apparatus for electrical testing of an electrical circuit according to claim 1 and wherein said at least one simulation electrode includes at least first and second simulation electrodes disposed adjacent respective ones of said first and second side surfaces of said electrical circuit.

3. Apparatus for electrical testing of an electrical circuit according to either of claims 1 and 2 and wherein said at least one sensing electrode includes at

least first and second sensing electrodes disposed adjacent respective ones of said first and second side surfaces of said electrical circuit.

4. Apparatus for electrical testing of an electrical circuit according to any of the preceding claims and also comprising at least one stimulation signal generator providing at least one stimulation signal to said at least one stimulation electrode.

5. Apparatus for electrical testing of an electrical circuit according to claim 4 and wherein said at least one stimulation signal generator provides stimulation signals to a plurality of stimulation electrodes in a manner such that signals induced in said electrical circuit by individual ones of said stimulation electrodes may be distinguished from each other.

6. Apparatus for electrical testing of an electrical circuit according to claim 5 and also comprising at least one separating detector for receiving from said at least one sensing electrode signals induced in said electrical circuit by individual ones of said stimulation electrodes and distinguishing said signals from each other.

7. Apparatus for electrical testing of an electrical circuit according to any of the preceding claims and also comprising a signal analyzer operative to analyze at least one signal received from said at least one sensing electrode.

8. Apparatus for electrical testing of an electrical circuit according to any of the preceding claims and also comprising a comparator receiving at least one signal derived from said resulting electromagnetic field and comparing said at least one signal with a reference.

9. Apparatus for electrical testing of an electrical circuit according to claim 8 and also comprising a defect report generator providing a defect report relating to said electrical circuit based on the output of said comparator.

10. Apparatus for electrical testing of an electrical circuit according to any of the preceding claims and wherein said at least one stimulation electrode comprises first and second stimulation electrodes arranged to be disposed alongside a first side of said electrical circuit and a third stimulation electrode arranged to be disposed alongside a second side of said electrical circuit.

11. Apparatus for electrical testing of an electrical circuit according to any of the preceding claims and wherein said at least one sensing electrode comprises a linear array of sensing electrodes.

12. Apparatus for electrical testing of an electrical circuit according to claim 10 and claim 11 and wherein said linear array is disposed intermediate said first and second stimulation electrodes.

13. Apparatus for electrical testing of an electrical circuit according to any of the preceding claims 1 - 9 and wherein said at least one stimulation electrode comprises a linear array of stimulation electrodes.

14. Apparatus for electrical testing of an electrical circuit according to any of the preceding claims 1 - 9 and wherein said at least one sensing electrode comprises first and second sensing electrodes arranged to be disposed alongside a first side of said electrical circuit and a third sensing electrode arranged to be disposed alongside a second side of said electrical circuit.

15. Apparatus for electrical testing of an electrical circuit according to any of the preceding claims 1 - 9 and wherein said at least one sensing electrode comprises first and second sensing electrodes arranged to be disposed alongside a first side of said electrical circuit.

16. Apparatus for electrical testing of an electrical circuit according to claim 13 and claim 14 or claim 15 and wherein said linear array is disposed intermediate said first and second stimulation electrodes.

17. Apparatus for electrical testing of an electrical circuit according to claim 5 and wherein said at least one signal generator provides signals having different frequencies to different ones of said stimulation electrodes.

18. Apparatus for electrical testing of an electrical circuit according to claim 5 and wherein said at least one signal generator provides multiplexed signals to different ones of said stimulation electrodes.

19. Apparatus for electrical testing of an electrical circuit according to any of the preceding claims and wherein said at least one stimulation electrode comprises a plurality of individually controllable sections.

20. A method for electrical testing of an electrical circuit having first and second side surfaces and including a plurality of conductors, the method comprising the steps of:

applying an electromagnetic field in a non-contact manner to at least one of first and second side surfaces of said electrical circuit; and

sensing a resulting electromagnetic field in a non-contact manner at various locations along at least one of said first and second side surfaces of said electrical circuit, wherein at least one of said applying and sensing steps employs non-contact electrodes disposed along both said first and second side surfaces of said electrical circuit.

21. A method for electrical testing of an electrical circuit according to claim 20 and wherein said applying step includes employing at least first and second simulation electrodes disposed adjacent respective ones of said first and second side surfaces of said electrical circuit to apply at least one electromagnetic field thereto.

22. A method for electrical testing of an electrical circuit according to either of claims 20 and 21 and wherein said sensing step includes employing at least first and second sensing electrodes disposed adjacent respective ones of said first and second side surfaces of said electrical circuit to sense said resulting electromagnetic field.

23. A method for electrical testing of an electrical circuit according to any of the preceding claims 20 - 22 and also comprising generating at least one stimulation signal and providing it to at least one stimulation electrode.

24. A method for electrical testing of an electrical circuit according to claim 23 and wherein said generating step provides stimulation signals to a plurality of stimulation electrodes in a manner such that signals induced in said electrical circuit by individual ones of said stimulation electrodes may be distinguished from each other.

25. A method for electrical testing of an electrical circuit according to claim 24 and also comprising receiving signals induced in said electrical circuit by individual stimulation electrodes and distinguishing said signals from each other.

26. A method for electrical testing of an electrical circuit according to any of the preceding claims 20 - 25 and also comprising analyzing at least one signal induced in said electrical circuit.

27. A method for electrical testing of an electrical circuit according to any of the preceding claims 20 - 26 and also comprising receiving at least one signal derived from said resulting electromagnetic field and comparing said at least one signal with a reference.

28. A method for electrical testing of an electrical circuit according to claim 27 and also comprising providing a defect report relating to said electrical circuit based on the comparing step.

29. A method for electrical testing of an electrical circuit according to any of the preceding claims 20 - 28 and wherein said applying step employs first and second stimulation electrodes disposed alongside a first side of said electrical circuit and a third stimulation electrode disposed alongside a second side of said electrical circuit.

30. A method for electrical testing of an electrical circuit according to any of the preceding claims 20 - 29 and wherein said sensing step employs a linear array of sensing electrodes.

31. A method for electrical testing of an electrical circuit according to claim 29 and claim 30 and wherein said linear array is disposed intermediate first and second stimulation electrodes.

32. A method for electrical testing of an electrical circuit according to any of the preceding claims 20 - 31 and wherein said applying step employs a linear array of stimulation electrodes.

33. A method for electrical testing of an electrical circuit according to any of the preceding claims 20 - 32 and wherein said sensing step employs first and second sensing electrodes disposed alongside a first side of said electrical circuit and a third sensing electrode disposed alongside a second side of said electrical circuit.

34. A method for electrical testing of an electrical circuit according to any of the preceding claims 20 - 32 and wherein said sensing step employs first and second sensing electrodes disposed alongside a first side of said electrical circuit.

35. A method for electrical testing of an electrical circuit according to claim 32 and claim 33 or claim 34 and wherein said linear array is disposed intermediate first and second stimulation electrodes.

36. A method for electrical testing of an electrical circuit according to claim 24 and wherein said generating step provides signals having different frequencies to different ones of said stimulation electrodes.

37. A method for electrical testing of an electrical circuit according to claim 24 and wherein said generating step provides multiplexed signals to different ones of said stimulation electrodes.

38. A method for electrical testing of an electrical circuit according to any of the preceding claims 20 - 37 and wherein said applying step employs at least one stimulation electrode comprising a plurality of individually controllable sections.

39. A method according to any of claims 20 - 38 and also comprising the step of grounding an intermediate metal layer in said electrical circuit.

40. A method according to any of claims 20 - 39 wherein said sensing step comprises sensing potentials on one side of the electrical circuit and sensing potentials on the opposite side of the electrical circuit.

41. A method for electrical testing of a multi-layered electrical circuit having first and second side surfaces and including a plurality of conductors, the method comprising the steps of:

grounding an intermediate metal layer in the electrical circuit;

inducing potentials into at least some of the conductors of said electrical circuit;

sensing a resulting electromagnetic field in a non-contact manner at various locations along at least said first side surface thereof to obtain electromagnetic field

data characteristic of the electrical circuit.

42. A method for electrical testing of a multi-layered electrical circuit according to claim 41 and also comprising sensing a resulting electromagnetic field at various locations along at least said second side surface thereof to obtain electromagnetic field data characteristic of the electrical circuit.

43. A method for electrical testing of a multi-layered electrical circuit according to either claim 41 and 42 wherein the electromagnetic field data is for the potential in conductors comprising the electrical circuit.

44. A method for electrical testing of a multi-layered electrical circuit according to any of claims 41 - 43 wherein said inducing step comprises inducing potentials on both a first side and a second side of the electrical circuit.

45. A method for electrical testing of a multi-layered electrical circuit according to claim 44 wherein inducing step comprises inducing potentials on the first side of the electrical circuit which are differentiable from potentials induced on the second side of the circuit.

46. A method for electrical testing of a multi-layered electrical circuit according to claim 45 wherein the inducing step comprises inducing potentials which are differentiable by frequency.

47. A method for electrical testing of a multi-layered electrical circuit according to claim 45 wherein the inducing step comprises inducing potentials which are multiplexed.

48. A method for electrical testing of a multi-layered electrical circuit according to any of claims 44 - 47 wherein the sensing step comprises sensing electromagnetic field data on one side of the electrical circuit.

49. A method for electrical testing of a multi-layered electrical circuit according to claim 48 wherein the sensing step further comprises distinguishing the electromagnetic field resulting from potentials induced on the first side of the electrical circuit from the electromagnetic field resulting from potentials induced on the second side of the electrical circuit.

50. A method for electrical testing of a multi-layered electrical circuit according to any of claims 41 - 43 wherein said inducing step comprises inducing potentials on a first side of the electrical circuit.

51. A method for electrical testing of a multi-layered electrical circuit according to claim 50 and claim 45 wherein the inducing step employs a plurality of stimulators, and each stimulator induces potentials which are differentiable by frequency.

52. A method for electrical testing of a multi-layered electrical circuit according to claim 50 and claim 45 wherein the inducing step employs a plurality of stimulators, and each stimulator induces potentials which are multiplexed.

53. A method for electrical testing of a multi-layered circuit according to any of claims 50 - 52 wherein the sensing step employs at least a first sensor and a second sensors arranged along a first side of the electrical circuit.

54. A method for electrical testing of a multi-layered electrical circuit according to claim 53 wherein the sensing step additionally employs a third sensor located along a second side of the electrical circuit.

55. A method for electrical testing of a multi-layered electrical circuit according to either claim 53 or 54 and also comprising correlating electromagnetic field data sensed by the sensors to a stimulator.

56. A method for electrical testing of a multi-layered electrical circuit according to any of claims 41 and 55 and also comprising determining electrical continuity of at least some of said conductors by comparing the electromagnetic field data to reference electromagnetic field data characteristic of a desired electrical circuit.

57. A method for electrical testing according to any of claims 41 - 57 and wherein said inducing step is carried out in a non-contact manner.

58. A method for electrical testing of a multi-layered electrical circuit having first and second side surfaces and including a plurality of conductors, the method comprising the steps of:

stimulating the electric circuit to induce in proximity thereto an electromagnetic field;

acquiring electromagnetic field data in a non-contact manner at various locations along the first side surface;

acquiring electromagnetic field data in a non-contact manner at various locations along the second side surface;

determining electrical continuity characteristics of said conductors by analysis of electromagnetic field data for the first side surface and by analysis of electromagnetic field data for the second side surface.

59. A method for electrical testing according to claim 58, wherein the analysis steps employs reference data characteristic of an electrical circuit having known structure.

60. A method for electrical testing according to either of claims 58 and 59, wherein the electrical circuit is a multi-layered circuit which comprises at least one intermediate layer which is substantially completely metalized, and the method includes grounding the at least one substantially completely metalized layer.

61. A method for electrical testing of an electrical circuit having a plurality of electrically conductive elements, the method comprising the steps of:

applying a first electromagnetic field to said electrical circuit with at least one stimulator located near but not contacting said article on a first side thereof;

applying a second electromagnetic field to said article at generally the same time as said first electromagnetic field with at least one stimulator located near but not contacting said article on a second side thereof;

separately detecting first and second potentials induced on said electrically conductive elements of the article by said first and second electromagnetic fields, respectively.

62. The method according to claim 61 and wherein the first and second steps of applying an electromagnetic field comprise the steps of generating electromagnetic signals of first and second frequencies, respectively.

63. The method according to claim 61 and wherein said step of separately detecting includes the step of sensing said potentials with at least one sensor located near said first side of said article.

64. The method according to any one of previous claims 61 - 63 and further comprising the step of scanning by at least one said sensor.

65. The method according to claim 64 and wherein said step of scanning includes the step of scanning in a first scanning direction and followed by the step of scanning in a second scanning direction which is substantially perpendicular to said first scanning direction.

66. The method according to claim 64 and wherein said step of scanning includes the step of scanning the article in a first position and followed by the step of scanning the article in a second position which is upside-down from said first position.

67. The method according to any of previous claims 60 - 66 and further comprising step of grounding internal metal layers of said article.

68. Apparatus for electrically testing an article having an electric circuit therein formed of a plurality of conductors, the apparatus comprising:

a first electromagnetic field generator applying a first electromagnetic field to said article, wherein said first field generator comprises at least one stimulator located near but not in contact with a first side of the article;

a second electromagnetic field generator applying a second electromagnetic field to said article, wherein said second field generator comprises at least one stimulator located near but not in contact with a second side of the article, wherein said second side is opposite said first side; and

a sensor operative to separately detect first and second potentials induced on the conductors by said first and second electromagnetic fields, respectively.

69. Apparatus for electrically testing an article according to claim 68 and wherein said sensor comprises an array of sensors adjacent to said at least one stimulator of said first field generator.

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70. Apparatus for electrically testing an article according to any of claims 68 – 69, wherein said first field generator generates an electromagnetic field at a first frequency, and said second field generator generates an electromagnetic field at a second frequency.

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71. Apparatus for electrically testing an article according to any of claims 68 – 70 and wherein said first field generator comprises a first stimulator and a second stimulator operative to generate the electromagnetic field.

15 72. Apparatus for electrically testing an article according to claim 71 and wherein said first stimulator and second stimulator each generate a field which are 180 degrees out of phase with respect to each other.

73. Apparatus for electrically testing an article according to any of 20 claims 68 – 72 and wherein at least one of said stimulators is made of a plurality of strip-shaped elements.

74. Apparatus for electrically testing an article according to claim 73 wherein said strip-shaped elements extend obliquely relative to said array of

sensors.

75. Apparatus for electrically testing an article according to any of claims 68 – 72, wherein at least one of said stimulators is made of a plurality of patch-shaped stimulators.

76. A method for electrically testing an article having a plurality of conductors therein, the method comprising the steps of:

subjecting a first side of the article to an electromagnetic field with at least one stimulator in close but not in contact arrangement with a first side of the article;

scanning said side of the article in at least two partially orthogonal directions with a not in contact sensor;

sensing potentials induced on the conductors by the electromagnetic field;

analyzing the potentials to determine the existence of defects in the elements.

77. A method according to claim 76, comprising the additional steps of:

subjecting a second side of the article to a second electromagnetic field with a second stimulator in close but not in contact arrangement with the second side;

scanning said side of the article in at least two at least partially orthogonal directions with a not in contact sensor and sensing the induction of potentials induced on the elements by the second electromagnetic field;

analyzing the potentials induced by the second electromagnetic field to determine the existence of defects in the elements.

78. The method according to claim 77 wherein said article is subjected to said first and second electromagnetic fields at generally the same time.

79. The method according to claim 78 wherein the electromagnetic fields are propagated at different frequencies.

80. The method according to claim 77 wherein the article comprises a metal layer, and the metal layer is grounded.

81. The method according to claim 77 wherein the article is subjected to the first and second electromagnetic fields one after the other.

82. A method for the electrical testing of an article having a plurality of electrically conductive elements and internal conductive layers, the method comprising the steps of:

subjecting the article to an electromagnetic field with at least one stimulator in close but not in contact arrangement with at least one side of the article;

grounding said internal conductive layers of said article;

scanning said at least one side of the article with a not in contact sensor and sensing the induction of potentials induced on the elements by the electromagnetic field;

analyzing the potentials to determine the existence of defects in the elements.